

Mars Human Precursor Study

Initial Findings and Next Steps

SMD/MEP De-Briefing to ESMD

7 February 2005





Agenda

- ***Overview of the SMD/Mars Exploration Program***
- ***Overview of the Human Precursor Task***
 - ***Summary of Measurement Panel Results & Priorities***
 - ***Summary of T/I Panel Results & Priorities***
- ***Summary of potential precursor activities***
- ***EDL application to MHP and the testbeds***
- ***Conclusions & Next Steps***

Introduction

Firouz Naderi

JPL/Mars Program Manager





MEP Timeline Leads to Next Decade Pathways

Launch Year

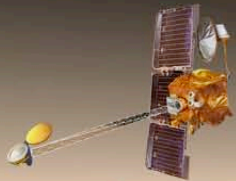
OPERATIONAL



Mars Global Surveyor



ESA
Mars Express



Mars Odyssey

2005



Mars
Reconnaissance
Orbiter
(Italian SHARAD)

2007

Competed Scout Mission



Phoenix

2009



Mars Telesat

Science pathways
responsive to discovery

...Next Decade

Explore the
Evolution of Mars

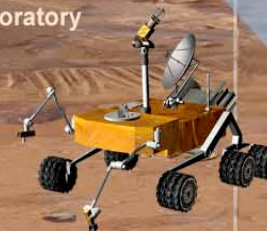
Search for
Evidence of Past Life

Search for Present Life

Explore
Hydrothermal
Habitats

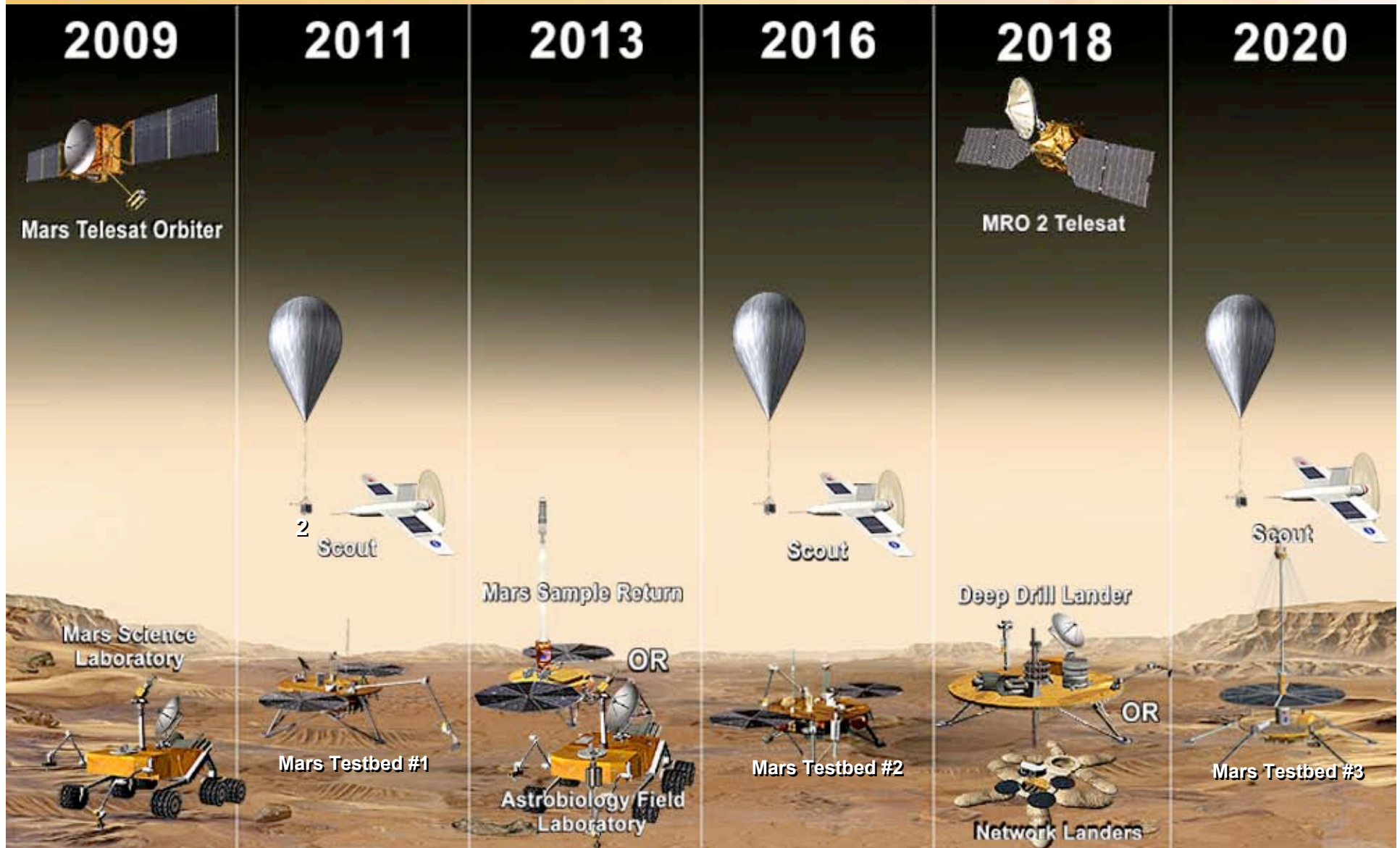
Mars
Exploration
Rovers

Mars Science
Laboratory





Next Decade of Mars Exploration Programs



2/27/05

***Mars Testbeds are human exploration pathfinders**

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Requirements Study Results

- Measurements Sub-Panel
- Technology & Infrastructure Sub-Panel

John Connolly
Jennifer Trosper
ESMD/Mars Coordinators



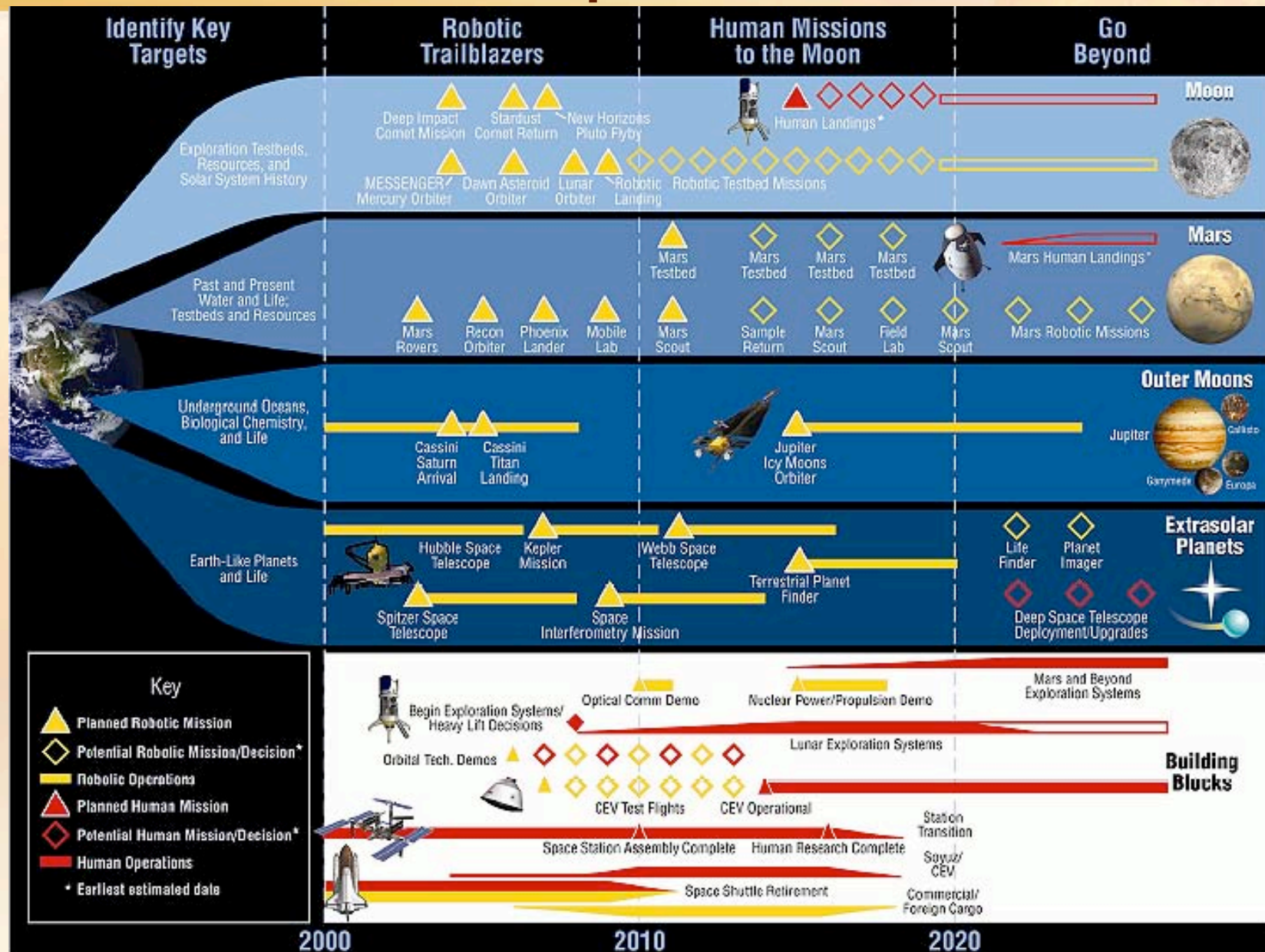


Top Level Mars Exploration Requirements Stem from Agency Roadmapping

1. Undertake robotic and human exploration of the Moon to further science and to enable sustained human and robotic exploration of Mars and other destinations. (Agency Objective 4)
2. **Conduct robotic exploration of Mars to search for evidence of life, to understand the history of the solar system, and to prepare for future human exploration. (Obj 5)**
Conduct human expeditions to Mars after acquiring adequate knowledge about the planet using robotic missions, and after successfully demonstrating sustained human exploration missions to the Moon. (Obj 6)
3. Conduct robotic exploration across the solar system to search for evidence of life, to understand the history of the solar system, to search for resources, and to support human exploration. (Obj 7)
4. Search for Earth-like planets and habitable environments around other stars. (Obj 8)
5. Develop a new crew exploration vehicle to provide crew transportation for missions beyond low Earth orbit. (Obj 10)
6. Focus research and use of the International Space Station on supporting space exploration goals, with emphasis on understanding how the space environment affects human health and capabilities, and developing countermeasures. (Obj 12)
7. Return the Space Shuttle to flight, complete assembly of the International Space Station, and transition from the Space Shuttle to a new exploration-focused transportation system. (Obj 11)
8. Explore our Universe to understand its origin, structure, evolution, and destiny. (Obj 9)
9. Explore the dynamic Earth system to understand sequences for life and the system, and will be experienced by human explorers. (Obj 2)
10. **Mars Robotic and Human Exploration Requirements**
11. Provide advanced aeronautical technologies to meet the challenges of next-generation systems in aviation, for civilian and scientific purposes, in our atmosphere and in the atmospheres of other worlds. (Obj 3)
12. Use NASA missions and other activities to inspire and motivate the nation's students and teachers, to engage and educate the public, and to advance the scientific and technological capabilities of the nation. (Obj 14)
13. Develop a comprehensive national plan for utilization of nuclear systems for the advancement of space science and exploration. (No Agency Obj)



Mars Exploration Program's Integral Role in Human Exploration





The Mars Human Precursor Study Task

- ESMD tasked the SMD/Mars Exploration Program to assist in the definition of the required mission set.
- The Mars Exploration Program Analysis Group (MEPAG) supported this task, as well as additional experts from NASA centers, academia, and industry.
 - 90 scientists and 25 engineers participated
- The task was kicked-off at the late June 2004 MEPAG meeting



Key Task Objectives

Task Lead: Frank Jordan

MEASUREMENT SUB-GROUP (Dave Beaty)

- Identify measurements that would reduce cost, risk and or enhance the overall mission success of future human missions to Mars.
 - prioritize and suggest required sequential relationships
 - identify where the measurements should be acquired
 - suggest the number of distinct sites for each measurement

TECHNOLOGY / INFRASTRUCTURE SUB-GROUP (Noel Hinnners)

- Identify technologies and infrastructure emplacement that would reduce cost, risk and or enhance the overall mission success of future human missions to Mars.

MISSION ARCHITECTURE TEAM (Frank Jordan)

- Describe in particular the measurement, technology, and infrastructure capabilities of potential testbed missions.



Categorizing the Results

Results of Measurement and Technology/Infrastructure Panels were categorized and prioritized by time-frame

- Early Phase—Leading to launches in 2011-2016
 - Influence architectural decisions for human missions
- Mid-Phase—Leading to launches in 2018-2022
 - Commitment to architectures for humans
 - Influence mission and flight system design decisions
- Late-Phase—Leading to launches in 2024-2028
 - Influence operability decisions
 - Landing site



Summary of Findings – Measurements

Highest Priority Objectives (of equal priority, timing of all is early with some being repeated at actual human site later)

1A) Characterization of dust properties for engineering impacts

- Measurements of shape, size distribution, mineralogy, electrical and thermal conductivity, triboelectric and photoemission properties, and chemistry (especially chemistry of relevance to predicting corrosion effects)

1B) Characterization of atmosphere to > 90 km for effects on Entry, Descent and Landing (EDL) and Take-off, ascent, orbit insertion (TAO)

- Measurements of pressure, density, temperature, opacity, directional wind speed

1C) Search for biohazards for human safety

- Biohazard search and identification in atmosphere, on surface, and in sub-surface

1D) Search and characterization of water for ISRU

- Search and characterization of equatorial water, mid-latitude water ice and polar near-surface ice



Summary of Findings – Measurements (con't)

Remaining Objectives (descending priority order)

2) Characterization of dust toxicity for human safety

- Measure for chemicals with known toxic effects on humans, soluble ion distributions, volatile release

3) Characterization of atmospheric electricity for effects on TAO and human occupation

- Measure DC and AC E fields, atmospheric and ground conductivity, grain charge and grain radius

4) Characterization of Martian environmental effects of terrestrial life contamination for potential impact on future science investigations

- Measure rate of destruction of organic material, mechanisms and rates for disbursement of organic materials, adhesion characteristics of organic contaminants



Summary of Findings – Measurements (con't)

Remaining Objectives (descending priority order)

- 5) Characterization of ionizing radiation environment at Martian surface for human safety
 - Measure distinguishing contributions from the energetic charged particles that penetrate the atmosphere, secondary neutrons produced in the atmosphere, and secondary charged particles and neutrons produced in the regolith
- 6) Determine traction / cohesion in martian soil/regolith for support of engineering design of surface assets
 - Measure cohesion, friction, density and variations
- 7) Determine meteorological properties of dust storms at ground level for understanding of effects on human occupation and EVA
 - Measure pressure, temperature, density, etc. as a function of time at the surface (over a Martian year or more)



Summary of Findings - Technology/ Infrastructure

Highest Priority Objectives (in priority order, early, mid, or late)

1A) Conduct a series of 3 aerocapture flight demonstrations

- 70 degree cone shaped, robotic scale (early)
- New entry vehicle configuration suitable for human exploration, robotic scale (mid)
- New entry vehicle configuration suitable for human exploration, large scale end-to-end mission demo (late)

1B) Conduct a series of 3 in-situ resource utilization technology demonstrations for life support and fuel systems

- ISRU atmospheric processing (early)
- ISRU regolith processing (early)
- ISRU human-scale application dress-rehearsal (late)

1C) Demonstrate an end-to-end system for soft, pinpoint Mars landing with 10m to 100m accuracy for testing of systems characteristics that are representative of Mars human exploration systems (mid)



Summary of Findings - Technology/ Infrastructure (con't)

Remaining Objectives (in priority order, early, mid, or late)

- 2A) Emplace continuous and redundant in-situ communications/navigation infrastructure for human mission support (late)
- 2B) Investigate long-term material degradation over times comparable to human mission needs for human systems design (mid)
- 3) Develop and demonstrate accurate, robust and autonomous Mars approach navigation for human mission safety (mid)

Requirements Flow-Down and Potential Precursor Missions

Frank Jordan
JPL/MEP Advanced Studies Czar





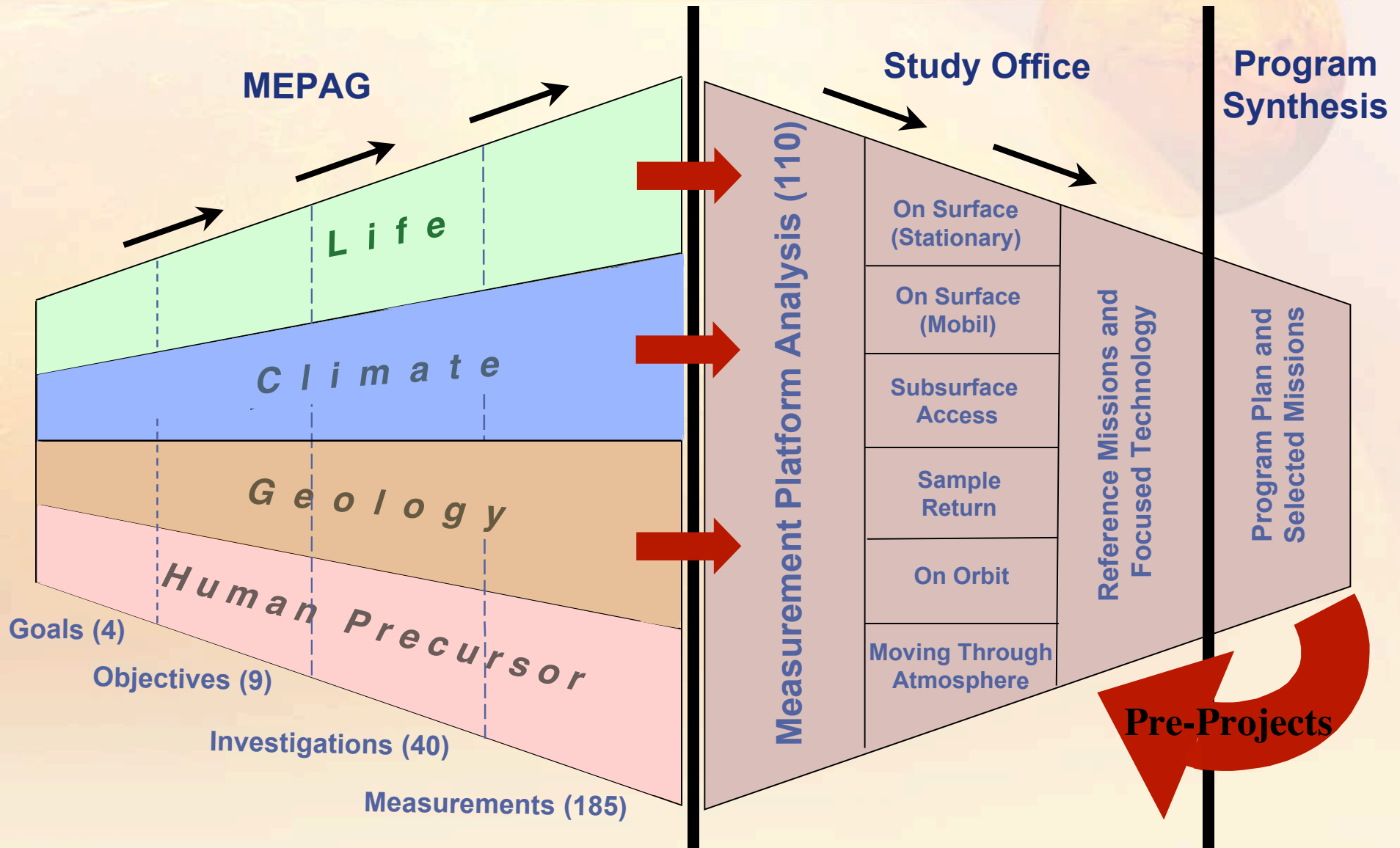
What we'll cover here is....

- *The advanced study process in MEP*
- *The measurement requirements, and what is addressed by the current science program*
- *What the gaps are*
- *Suggested actions for – –*
 - *System Studies*
 - *Technology*
 - *Potential Precursor Missions*



Advanced Studies Process

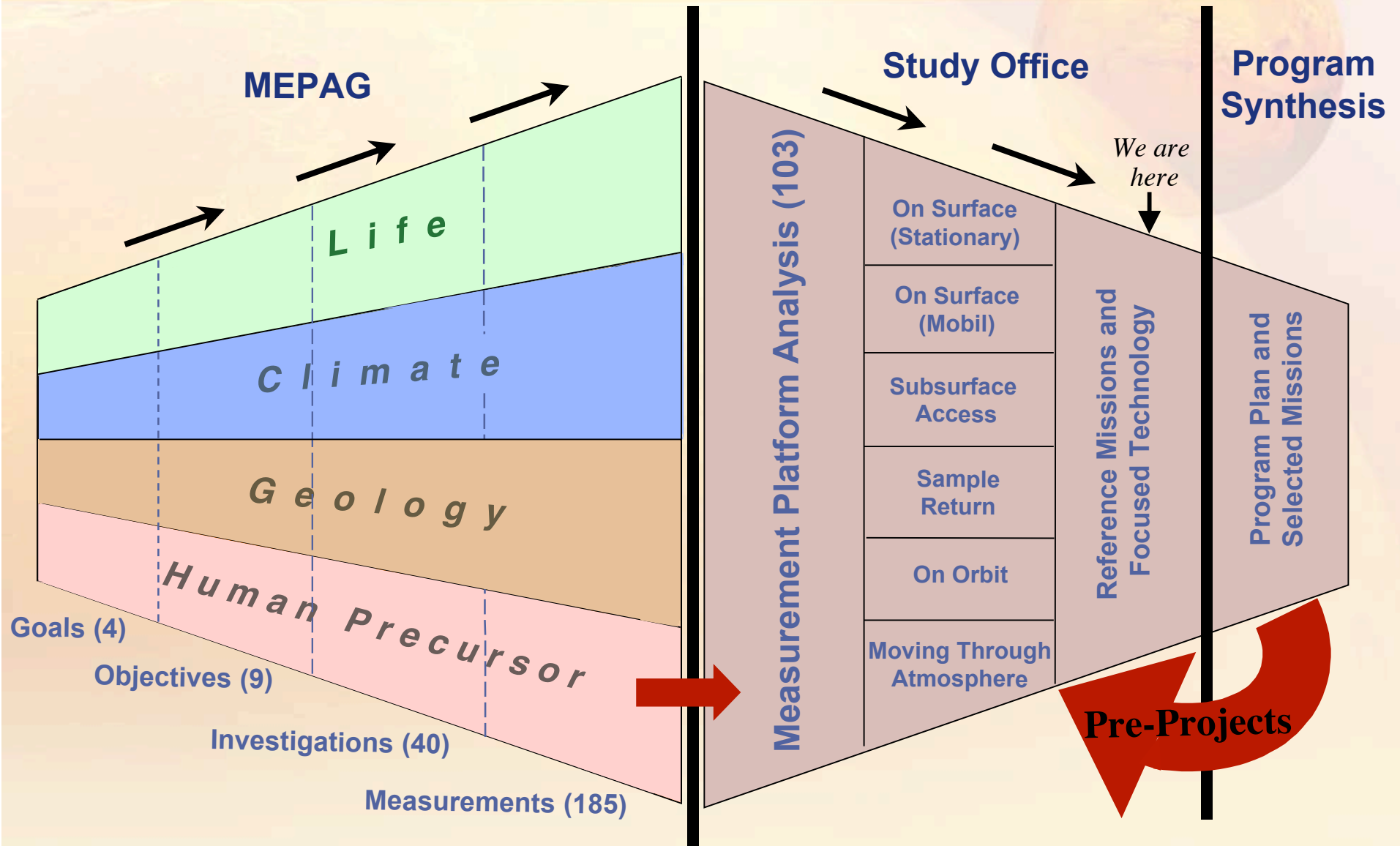
(Before the Exploration Vision)





Advanced Studies Process

(2005 – After the Vision)





Science Missions Considered in This Analysis

CURRENT PROGRAM

Odyssey (on-orbit)
Mars Global Surveyor (MGS—on-orbit)
Mars Exploration Rovers (MER—on the surface)
Mars Express (ESA—on-orbit)
Mars Reconnaissance Orbiter (MRO--2005)
Mars Scout Phoenix (Scout; 2007)
Mars Science Laboratory (MSL—2009)
Mars Telecommunications Orbiter (MTO—2009)

FUTURE MISSIONS

Mars Sample Return (MSR)
Astrobiology Field Laboratory (AFL)



MHP Requirements Comparison to MEP Science Mission Objectives

		MHP SSG Investigation	MHP SSG Measurement Category
GOAL IV.A. Precursor Measurements	DUST - ENGINEERING EFFECTS		Characterize surface soil (Early)
			Characterize suspended dust (Early)
			Characterize dust from storm (Mid)
			Soil from different locations (Mid)
	ATMOSPHERE (EDL/TAO)		Upper, middle & lower - EDL (Early)
			Surface parameters over time (Early)
			Long-term orbital remote sensing (Early)
			EDL/TAO ascent/descent probes (Late)
	BIOHAZARDS		Draft Test Protocol (Mid)
			Organics at future landing site (Late)
	ISRU WATER		Equatorial water ground truth (Early)
			Ice deposits: 40-55 deg latitude (Early)
			Polar near-surface water/ice (Early)
			Other locations/depths (Mid)
	DUST TOXICITY		Toxicity - at least one site (Mid)
			Surface dust/water reactions (Mid))
			Dust grains shape (Mid)
	ATM. ELECTRICITY		Toxic effects in human surrogates (Mid)
			Electrical properties at surface (Mid)
	FORWARD PLANETARY PROTECTION		Electrical properties at surface with MET (Mid)
			Environmental effects on organics (Mid)
			Aeolian effects on organics (Mid)
			Organic contamination by landed HW (Mid)
GOAL IV.B. Eng./TI Demos	RADIATION		Surface-subsurface organic transport (Mid)
			Charged particles at surface (Mid)
			Neutrons (Mid)
			Radiation shielding ability of soil/regolith (Mid)
	SURFACE TRAFFICABILITY		Simultaneous orbital SEP events w/surface (Mid)
			Vertical soil density profile (Mid)
			Internal angle of friction (Mid)
			Soil Cohesion (Mid)
	DUST STORM METEOROLOGY		Precision imaging of sites (Mid)
			Surface dust storm weather (Mid)
	AEROCAPTURE		Long-term weather from orbit (Mid)
			70 deg sphere cone shape (Early)
			New shape robotic scale (Mid)
			New shape human scale (Late)
	ISRU DEMOS		ISRU Atmospheric Processing (Early)
			ISRU Regolith-Water Processing (Early)
			ISRU Human-scale dress rehearsal (Late)
	PINPOINT LAND.		10m - 100m accuracy (Mid)
	COMM. INFRAST.		Continuous & redundant in situ comm (Late)
	MATERIALS		Materials degradation over time (Mid)
	APPROACH NAV		Accurate, robust, autonomous (Mid)

Fill color indicates how well the cumulative capabilities of the current MEP portfolio fulfills the requirement

Requirement Fully Addressed
Requirement Possibly Addressed
Requirement Partially Addressed
Requirement Not Addressed

NOTE: The assignment of color is somewhat subjective and intended as a general indication of effectiveness in meeting MHP SSG requirements.



Requirements Likely Completed By Science Missions

		MHP SSG Investigation	MHP SSG Measurement Category	Requirement Fully Addressed
GOAL IV.A. Precursor Measurements	DUST - ENGINEERING EFFECTS		Characterize surface soil (Early)	<ul style="list-style-type: none"> Characterize surface soil (Early) (MSR) Soil from different locations (Mid) (MSR)
			Characterize suspended dust (Early)	
			Characterize dust from storm (Mid)	
			Soil from different locations (Mid)	
	ATMOSPHERE (EDL/TAO)		Upper, middle & lower - EDL (Early)	<ul style="list-style-type: none"> Surface biohazard evaluation (Mid) (MSR)
			Surface parameters over time (Early)	
			Long-term orbital remote sensing (Early)	
			EDL/TAO ascent/descent probes (Late)	
	BIOHAZARDS		Draft Test Protocol (Mid)	<ul style="list-style-type: none"> Dust toxicity (Mid) (MSR)
			Organics at future landing site (Late)	
	ISRU WATER		Equatorial water ground truth (Early)	<ul style="list-style-type: none"> Precision imaging (Mid) (MGS, MRO) Accurate, robust, and autonomous approach navigation (Mid) (MRO, MSR, MTO)
			Ice deposits: 40-55 deg latitude (Early)	
			Polar near-surface water/ice (Early)	
			Other locations/depths (Mid)	
	DUST TOXICITY		Toxicity - at least one site (Mid)	<ul style="list-style-type: none"> Accurate, robust, and autonomous approach navigation (Mid) (MRO, MSR, MTO)
			Surface dust/water reactions (Mid)	
			Dust grains shape (Mid)	
			Toxic effects in human surrogates (Mid)	
	ATM. ELECTRICITY		Electrical properties at surface (Mid)	<ul style="list-style-type: none"> Accurate, robust, and autonomous approach navigation (Mid) (MRO, MSR, MTO)
			Electrical properties at surface with MET (Mid)	
	FORWARD PLANETARY PROTECTION		Environmental effects on organics (Mid)	<ul style="list-style-type: none"> Accurate, robust, and autonomous approach navigation (Mid) (MRO, MSR, MTO)
			Aeolian effects on organics (Mid)	
			Organic contamination by landed HW (Mid)	
			Surface-subsurface organic transport (Mid)	
	RADIATION		Charged particles at surface (Mid)	<ul style="list-style-type: none"> Accurate, robust, and autonomous approach navigation (Mid) (MRO, MSR, MTO)
			Neutrons (Mid)	
			Radiation shielding ability of soil/regolith (Mid)	
			Simultaneous orbital SEP events w/surface (Mid)	
GOAL IV.B. Eng./TI Demos	SURFACE TRAFFICABILITY		Vertical soil density profile (Mid)	<ul style="list-style-type: none"> Accurate, robust, and autonomous approach navigation (Mid) (MRO, MSR, MTO)
			Internal angle of friction (Mid)	
			Soil Cohesion (Mid)	
			Precision imaging of sites (Mid)	
	DUST STORM METEOROLOGY		Surface dust storm weather (Mid)	<ul style="list-style-type: none"> Accurate, robust, and autonomous approach navigation (Mid) (MRO, MSR, MTO)
			Long-term weather from orbit (Mid)	
	AEROCAPTURE		70 deg sphere cone shape (Early)	<ul style="list-style-type: none"> Accurate, robust, and autonomous approach navigation (Mid) (MRO, MSR, MTO)
			New shape robotic scale (Mid)	
			New shape human scale (Late)	
			ISRU Atmospheric Processing (Early)	
	ISRU DEMOS		ISRU Regolith-Water Processing (Early)	<ul style="list-style-type: none"> Accurate, robust, and autonomous approach navigation (Mid) (MRO, MSR, MTO)
			ISRU Human-scale dress rehearsal (Late)	
	PINPOINT LAND.		10m - 100m accuracy (Mid)	<ul style="list-style-type: none"> Accurate, robust, and autonomous approach navigation (Mid) (MRO, MSR, MTO)
	COMM. INFRAST.		Continuous & redundant in situ comm (Late)	
	MATERIALS		Materials degradation over time (Mid)	
	APPROACH NAV		Accurate, robust, autonomous (Mid)	



Requirements Possibly Completed By Science Missions

MHP SSG Investigation		MHP SSG Measurement Category
GOAL IV.A. Precursor Measurements	DUST - ENGINEERING EFFECTS	Characterize surface soil (Early)
		Characterize suspended dust (Early)
		Characterize dust from storm (Mid)
		Soil from different locations (Mid)
	ATMOSPHERE (EDL/TAO)	Upper, middle & lower - EDL (Early)
		Surface parameters over time (Early)
		Long-term orbital remote sensing (Early)
		EDL/TAO ascent/descent probes (Late)
	BIOHAZARDS	Draft Test Protocol (Mid)
		Organics at future landing site (Late)
	ISRU WATER	Equatorial water ground truth (Early)
		Ice deposits: 40-55 deg latitude (Early)
		Polar near-surface water/ice (Early)
		Other locations/depths (Mid)
	DUST TOXICITY	Toxicity - at least one site (Mid)
		Surface dust/water reactions (Mid)
		Dust grains shape (Mid)
		Toxic effects in human surrogates (Mid)
	ATM. ELECTRICITY	Electrical properties at surface (Mid)
		Electrical properties at surface with MET (Mid)
	FORWARD PLANETARY PROTECTION	Environmental effects on organics (Mid)
		Aeolian effects on organics (Mid)
		Organic contamination by landed HW (Mid)
		Surface-subsurface organic transport (Mid)
	RADIATION	Charged particles at surface (Mid)
		Neutrons (Mid)
		Radiation shielding ability of soil/regolith (Mid)
		Simultaneous orbital SEP events w/surface (Mid)
	SURFACE TRAFFICABILITY	Vertical soil density profile (Mid)
		Internal angle of friction (Mid)
		Soil Cohesion (Mid)
	DUST STORM METEOROLOGY	Precision imaging of sites (Mid)
		Surface dust storm weather (Mid)
		Long-term weather from orbit (Mid)
GOAL IV.B. Eng./TI Demos	AEROCAPTURE	70 deg sphere cone shape (Early)
		New shape robotic scale (Mid)
		New shape human scale (Late)
	ISRU DEMOS	ISRU Atmospheric Processing (Early)
		ISRU Regolith-Water Processing (Early)
		ISRU Human-scale dress rehearsal (Late)
	PINPOINT LAND.	10m - 100m accuracy (Mid)
	COMM. INFRASTR.	Continuous & redundant in situ comm (Late)
	MATERIALS	Materials degradation over time (Mid)
	APPROACH NAV	Accurate, robust, autonomous (Mid)

Requirement Possibly Addressed

- EDL Atmospheric Variations (Early)
(MSL, MSR, AFL)
- Viking Heritage Aerocapture (Early)
(MSR)
- Pinpoint Landing (Mid)
(MSL, MSR)



Requirements Partially Addressed By Science Missions (Example: Dust)

	MHP SSG Investigation	MHP SSG Measurement Category
GOAL IV.A. Precursor Measurements	DUST - ENGINEERING EFFECTS	Characterize surface soil (Early)
		Characterize suspended dust (Early)
		Characterize dust from storm (Mid)
		Soil from different locations (Mid)
	ATMOSPHERE (EDL/TAO)	Upper, middle & lower EDL (Early)
		Surface parameters over time (Early)
		Long-term orbital remote sensing (Early)
	BIOHAZARDS	EDL/TAO ascent/descent probes (Late)
		Draft Test Protocol (Mid)
	ISRU WATER	Organics at future landing site (Late)
		Equatorial water ground truth (Early)
		Ice deposits: 40-55 deg latitude (Early)
		Polar near-surface water/ice (Early)
	DUST TOXICITY	Other locations/depths (Mid)
		Toxicity - at least one site (Mid)
		Surface dust/water reactions (Mid)
		Dust grains shape (Mid)
GOAL IV.B. Eng./TI Demos	ATM. ELECTRICITY	Toxic effects in human surrogates (Mid)
		Electrical properties at surface (Mid)
	FORWARD PLANETARY PROTECTION	Electrical properties at surface with MET (Mid)
		Environmental effects on organics (Mid)
		Aeolian effects on organics (Mid)
		Organic contamination by landed HW (Mid)
	RADIATION	Surface-subsurface organic transport (Mid)
		Charged particles at surface (Mid)
		Neutrons (Mid)
		Radiation shielding ability of soil/regolith (Mid)
	SURFACE TRAFFICABILITY	Simultaneous orbital SEP events w/surface (Mid)
		Vertical soil density profile (Mid)
		Internal angle of friction (Mid)
	DUST STORM METEOROLOGY	Soil Cohesion (Mid)
		Precision imaging of sites (Mid)
	AEROCAPTURE	Surface dust storm weather (Mid)
		Long-term weather from orbit (Mid)
		70 deg sphere cone shape (Early)
	ISRU DEMOS	New shape robotic scale (Mid)
		New shape human scale (Late)
		ISRU Atmospheric Processing (Early)
	PINPOINT LAND.	ISRU Regolith-Water Processing (Early)
		ISRU Human-scale dress rehearsal (Late)
	COMM. INFRASTR.	10m - 100m accuracy (Mid)
	MATERIALS	Continuous & redundant in situ comm (Late)
	APPROACH NAV	Materials degradation over time (Mid)
		Accurate, robust, autonomous (Mid)

Requirement Partially Addressed

• Surface atmospheric parameters (Early) (MER, Phoenix, MSL)

Gap:

- T, P, density, wind speed, and opacity measurement requirements not met

• Long-term orbital remote sensing (Early) (MGS, Odyssey, MEx, MRO)

Gap:

- No orbiters currently performing direct wind speed measurements
- Insufficient vertical spatial resolution (T, P)

• Organics at future landing site (Late) (Phoenix, MSL, MSR, AFL)

Gap:

- AFL provides some organic analysis -- must occur after MSR data analysis



Requirements Likely Not Addressed By Science Missions

		Requirement Not Addressed	
GOAL IV.A. Precursor Measurements	MHP SSG Investigation	MHP SSG Measurement Category	
	DUST - ENGINEERING EFFECTS	Characterize surface soil (Early)	Characterize suspended dust (Early)
		Characterize suspended dust (Early)	Characterize dust from storm (Mid)
		Characterize dust from storm (Mid)	Soil from different locations (Mid)
		Soil from different locations (Mid)	
	ATMOSPHERE (EDL/TAO)	Upper, middle & lower EDL (Early)	EDL/TAO ascent/descent probes (Late)
		Surface parameters over time (Early)	
		Long-term orbital remote sensing (Early)	
		EDL/TAO ascent/descent probes (Late)	
	BIOHAZARDS	Draft Test Protocol (Mid)	Forward Planetary Protection (Mid)
		Organics at future landing site (Late)	
	ISRU WATER	Equatorial water ground truth (Early)	Radiation shielding ability of soil/regolith (Mid)
		Ice deposits: 40-55 deg latitude (Early)	
		Polar near-surface water/ice (Early)	
		Other locations/depths (Mid)	
	DUST TOXICITY	Toxicity - at least one site (Mid)	Simultaneous orbital SEP and surface radiation measurements (Mid)
		Surface dust/water reactions (Mid)	
		Dust grains shape (Mid)	
	ATM. ELECTRICITY	Toxic effects in human surrogates (Mid)	
		Electrical properties at surface (Mid)	
	FORWARD PLANETARY PROTECTION	Electrical properties at surface with MET (Mid)	Aerocapture new shape robotic scale (Mid)
		Environmental effects on organics (Mid)	
		Aeolian effects on organics (Mid)	
		Organic contamination by landed HW (Mid)	
GOAL IV.B. Eng./TI Demos	RADIATION	Surface-subsurface organic transport (Mid)	Aerocapture new shape human scale (Late)
		Charged particles at surface (Mid)	
		Neutrons (Mid)	
		Radiation shielding ability of soil/regolith (Mid)	
	SURFACE TRAFFICABILITY	Simultaneous orbital SEP events w/surface (Mid)	ISRU atmospheric processing (Early)
		Vertical soil density profile (Mid)	
		Internal angle of friction (Mid)	
	DUST STORM METEOROLOGY	Soil Cohesion (Mid)	ISRU regolith-water processing (Early)
		Precision imaging of sites (Mid)	
		Surface dust storm weather (Mid)	ISRU human-scale dress rehearsal (Late)
		Long-term weather from orbit (Mid)	
	AEROCAPTURE	70 deg sphere cone shape (Early)	Materials degradation over time (Mid)
		New shape robotic scale (Mid)	
		New shape human scale (Late)	
	ISRU DEMOS	ISRU Atmospheric Processing (Early)	
		ISRU Regolith-Water Processing (Early)	
		ISRU Human-scale dress rehearsal (Late)	
	PINPOINT LAND.	10m - 100m accuracy (Mid)	
	COMM. INFRASTR.	Continuous & redundant in situ comm (Late)	
	MATERIALS	Materials degradation over time (Mid)	
	APPROACH NAV	Accurate, robust, autonomous (Mid)	



Requirements “Gaps” Mapped to Measurement Methods

Requirement Possibly Addressed

Requirement Partially Addressed

Requirement Not Addressed

Focus is on high priority
early- and mid-phase
requirements not likely to be
addressed by the science
program

Goal IV Requirement → Candidate Measurement/Instrument → Platform



Measurement-to-Platform Mapping (Example chart)

MHP SSG Investigation	MHP SSG Measurement Category	Gap Measurements	Candidate Instrument Type(s)	Platform(s)
DUST - ENGINEERING EFFECTS	Characterize suspended dust (Early)	Magnitude and polarity of dust charging, concentration of free ions	Dust (charged particle) analysis instrument	surface stationary-or-mobile
	Characterize dust from storm (Mid)	Collection and concurrent measurements of airborne dust during a dust storm (shape/size, mineralogy, electrical and thermal conductivity, triboelectric properties, photoemission, and chemistry)	<i>In situ</i> complete dust analysis suite (Soil wetchem instr, electrometer, AFM, visible microscopy, GCMS, XRD/XRF, Raman, EPR, LIBS, Raman, DC 4-terminal, Thermocouple) with dust storm sample collection	surface stationary-or-mobile
ATMOSPHERE (EDL/TAO)	Upper, middle & lower - EDL (Early)	Atmospheric T, P, v, and density during EDL (ground to 90 km altitude)	T sensor, P sensor, accelerometers, gyros	vehicle moving through atmosphere
	Surface parameters over time (Early)	Surface atmospheric direct measurements of P, T, v, and opacity at as many locations as possible.	MET packages (T sensor, P sensor, anemometer, LIDAR) at multiple locations	surface stationary-or-mobile*
	Long-term orbital remote sensing (Early)	High vertical spatial resolution T, P measurements.	IR and microwave limb sounders	orbiting
		Direct wind speed measurements.	LIDAR	orbiting
ISRU WATER	Equatorial water ground truth (Early)	In top few meters of regolith, bulk regolith concentration of water/volatiles, as well as impurities released with regolith heating	Capture/detection of volatile release (i.e. TDL spectroscopy during drilling) or collection/chemical analysis of non-volatilized sample (i.e. GCMS)	Platform options: 1. subsurface 2. subsurface plus surface stationary-or-mobile
		Map bulk water concentration within top few meters over a 100m X 100 m X 2m deep area.	Capture/detection of volatile release (i.e. TDL spectroscopy during drilling) or collection/chemical analysis of non-volatilized sample (i.e. GCMS) plus GPR, neutron (surface mobile)	Platform options: 1. subsurface plus surface mobile 2. Subsurface plus surface stationary-or-mobile plus surface mobile
		Map bulk volatile concentration over a 100m X 100 m X 2m deep area.	Capture/detection of volatile release (i.e. TDL spectroscopy during drilling) or collection/chemical analysis of non-volatilized sample (i.e. GCMS) plus GPR, neutron (surface mobile)	Platform options: 1. subsurface plus surface mobile 2. Subsurface plus surface stationary-or-mobile plus surface mobile

* Requires measurements from as many locations as possible - benefits from surface stationary network



Resulting Platform Requirements

Number of MHP SSG Goal IV “Gap” measurements addressed by each platform type, by phase.

<i>PLATFORM</i>	<i>EARLY</i>	<i>MID</i>	<i>TOTAL</i>
<i>SURFACE STATIONARY-OR-MOBILE</i> <i>(MOBILITY NOT REQUIRED)</i>	<i>16</i>	<i>34</i>	<i>50</i>
<i>SURFACE MOBILE</i> <i>(MOBILITY REQUIRED)</i>	<i>6</i>	<i>3</i>	<i>9</i>
<i>SUBSURFACE</i>	<i>13</i>	<i>1</i>	<i>14</i>
<i>ORBITING</i>	<i>7</i>	<i>3</i>	<i>10</i>
<i>VEHICLE MOVING THROUGH ATMOSPHERE</i>	<i>6</i>	<i>2</i>	<i>8</i>



Recommendations for Follow-On Work

- ***Mission & System Studies*** (Now)
- ***Technologies*** (This Decade)
- ***Precursor Missions*** (Next Decade)



Mission and System Study Recommendations (Now)

<i>Key Study Subject List</i>	<i>Budget in Millions of Dollars</i>	
	FY05	FY06
• <i>Continuing robotic mission design studies for testbeds</i>	1	1
• <i>Robotic landing new configuration study (scalable to human landing size)</i>	1	4 *
• <i>Water location and accessibility</i>	.5	.5
• <i>ISRU potential</i>	.5	2 *
• <i>Human landing site characterization</i>	.5	.5
• <i>Human mission architecture studies</i>	1	3 *



Technology Investment Areas (Near-Term)

Investments are needed to enable precursor missions in the next decade

Human Scalable Landing Technologies

- Aeromaneuver
- Decelerators
- Pin-point accuracy – soft landing

ISRU

- Excavation
- Chemical processing

Environmental Measurement Instruments



Next Decade Precursor Mission Possibilities

- Take advantage of the Science Program to meet several of the human precursor needs
 - Ensure fulfillment of compatible ESDM/SMD requirements
 - Consider:
 - Instrumentation of all EDL vehicles
 - Meteorological stations on all Landers and Orbiters
- Testbed Missions (early next decade) that concentrate on the “gap” requirements, by priority
 - Expand environmental measurements
 - Characteristics of human-scale landing systems (i.e., pinpoint landing, aerocapture)
 - ISRU/water location and characterization
- Target a major subscale (but human-scalable) landing and ISRU demo by the latter part of the next decade
 - Would lead to a “commitment to architecture” by around 2020



Some Precursor Mission Ideas For Early Next Decade

Stationary Surface Lander

- *Environment Measurements*
- *Atmosphere ISRU Demo and/or Regolith*
- *Pinpoint Landing*
- *Water Ground Truth*



Orbiter *

- *Aerocapture Demo*
- *Meteorological Station*
- *GPR Water Mapping*



Surface Mobility Mission

- *Mapping of near-surface water*
 - *Neutron Detector – Hydrates*
 - *GPR – Ice*



Multi-Hard Lander Network

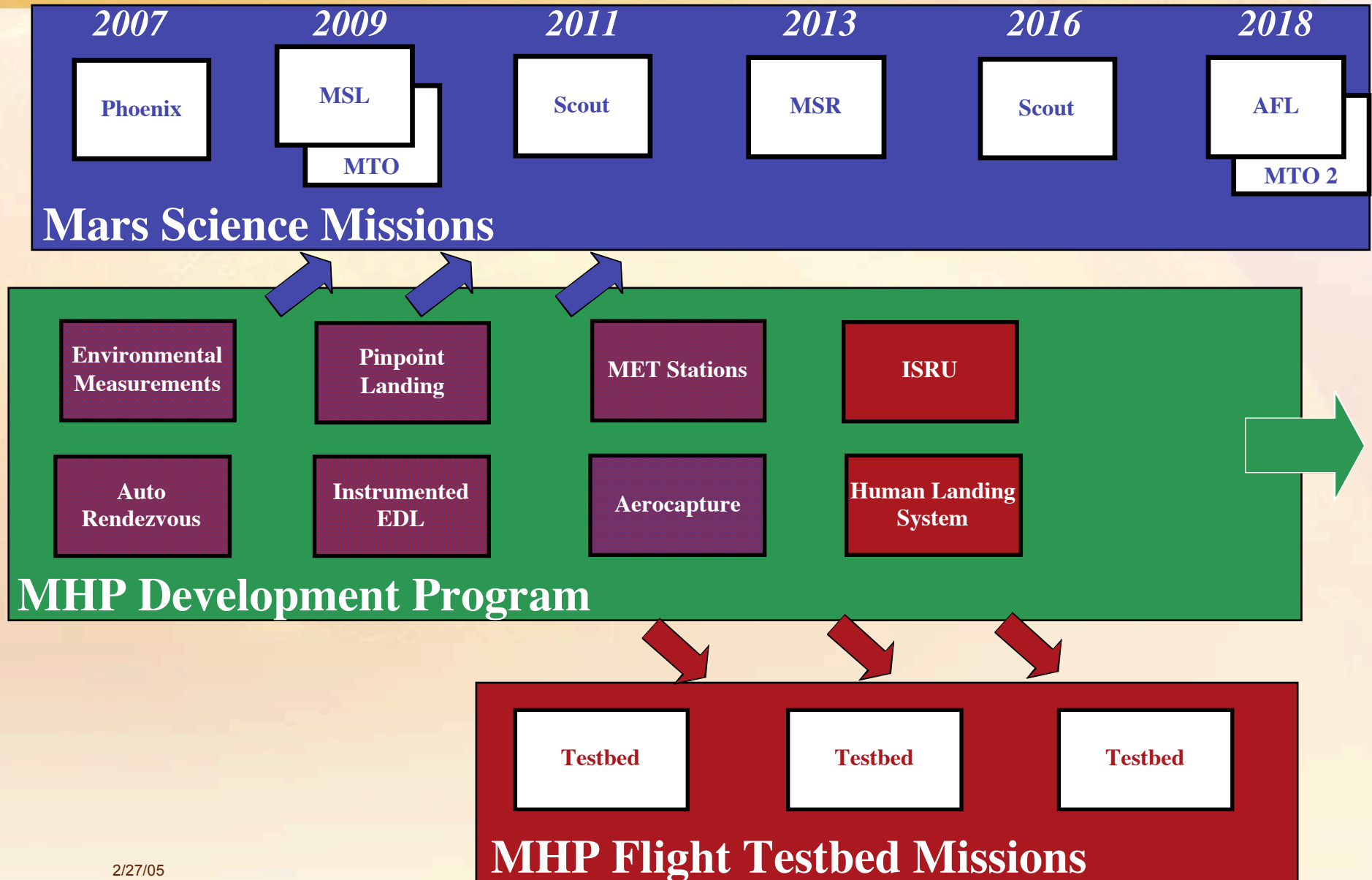
- *Met Stations, Water Ground Truth*
- *Environment Measurements*



Note: These need to be fleshed out and validated against requirements by a joint team



An Integrated Mars Science Program with MHP Activities



Thoughts on the Challenges of Landing on Mars

Rob Manning
JPL/MEP

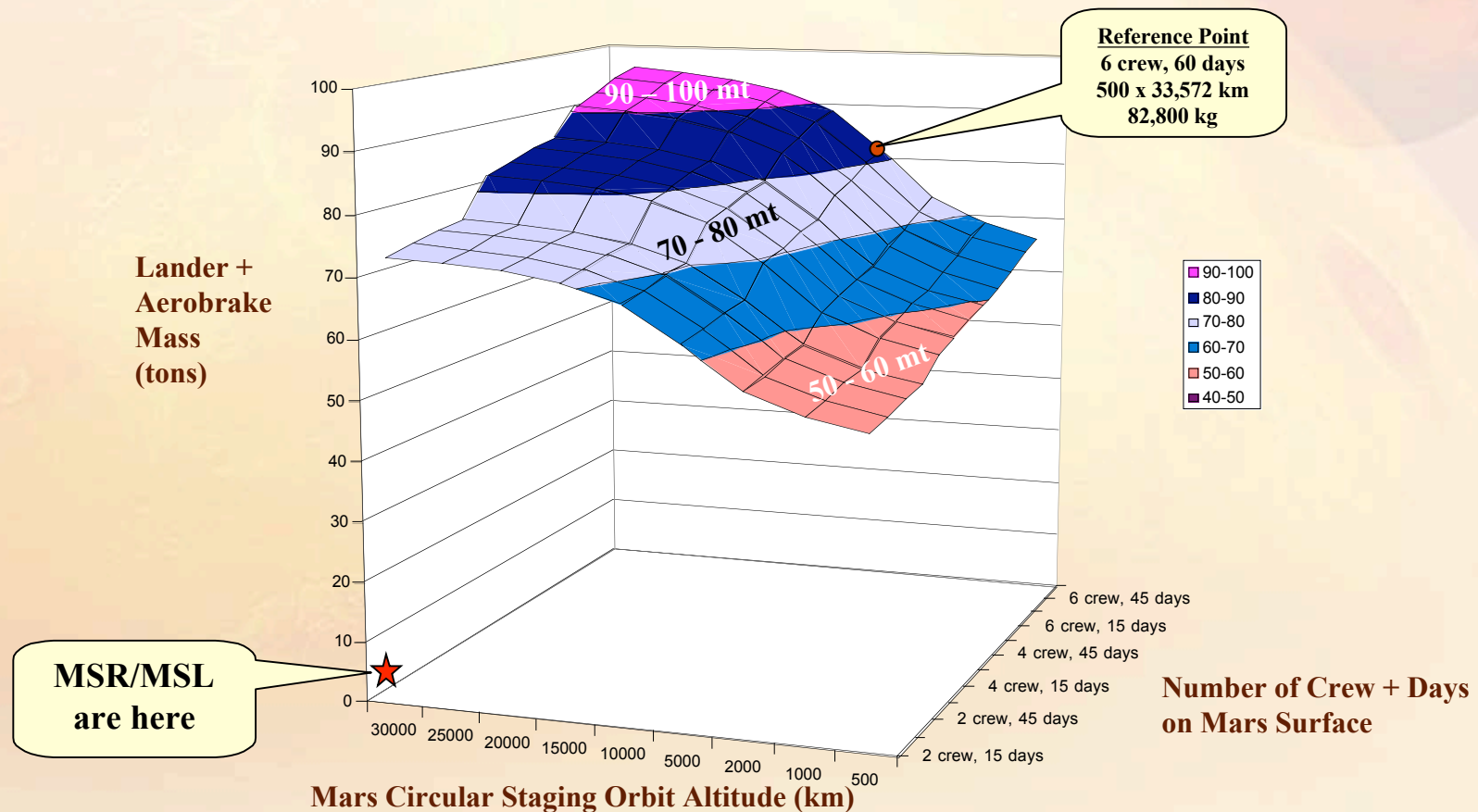




Scale

Lander Mass at Mars Atmospheric Entry

- Human missions will require landed masses in the tens of tons*



Courtesy: J. Geffre/JSC



First Challenge is to get the Mass Down

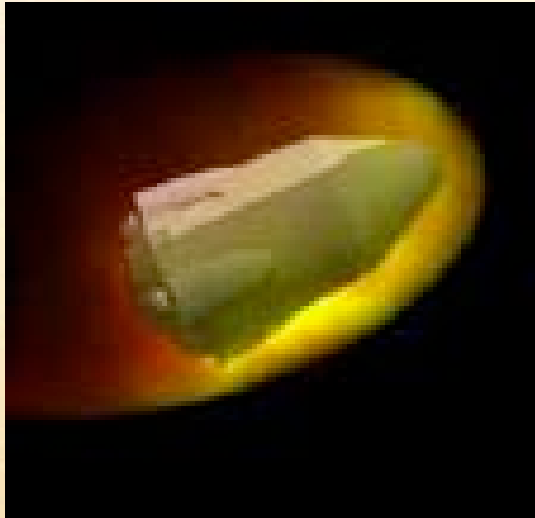
- Below shows the number of “landed payloads” needed to get to the surface at each key mission phase for four “places” (two real ones)
 - It takes a lot of mass to get to Mars. (And even more to get back.)
- The atmosphere of Mars is a harsh mistress. To squeeze the mass down, she calls us to use it (aero-assist).
 - But it also forces us into regimes that differ greatly from lunar systems.

	LEO-> Transfer Orbit	Transfer Orbit -> Low Orbit	Low Orbit -> Surface
Moon			
Total Delta V (km/s)	3.1	0.8	2.0
Total # of Landed Payloads before Delta-V	8.6	3.1	2.3
Moon "at Mars"			
Total Delta V (km/s)	3.6	1.9	2.0
Total # of Landed Payloads before Delta-V	16.5	4.9	2.3
Mars at Mars (All prop, no Atm.)			
Total Delta V (km/s)	3.6	2.1	4.2
Total # of Landed Payloads before Delta-V	70.0	20.9	8.7
Mars at Mars (Aero-assisted)			
Total Delta V (km/s)	3.6	2.1	4.2
Total # of Landed Payloads before Delta-V	11.0	3.3	2.2



Second Challenge is to get the Vehicle Down

How do we get from here ...



to here ...



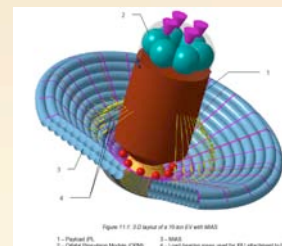
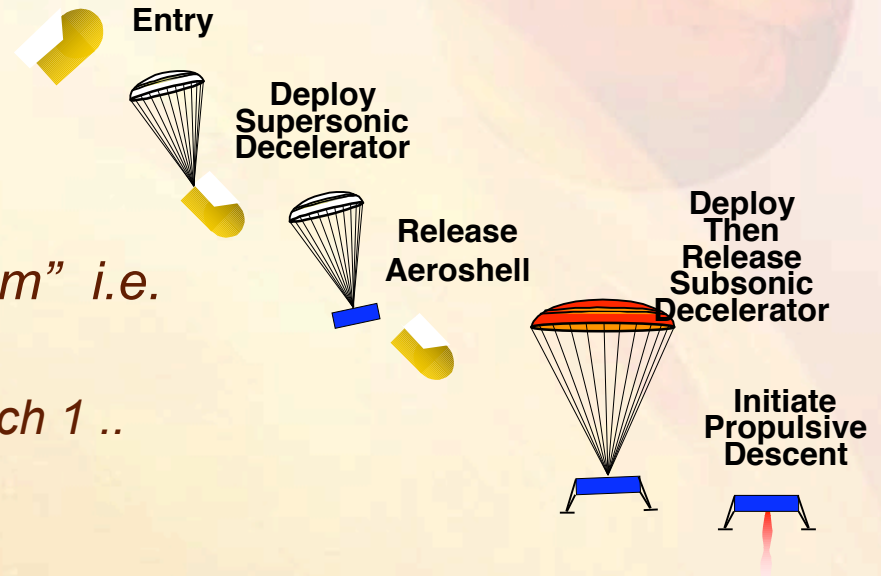
in 90 seconds??



Second Challenge is to get the Vehicle Down

- *While by no means easy, think we understand how to enter Mars hypersonically, but we then face*

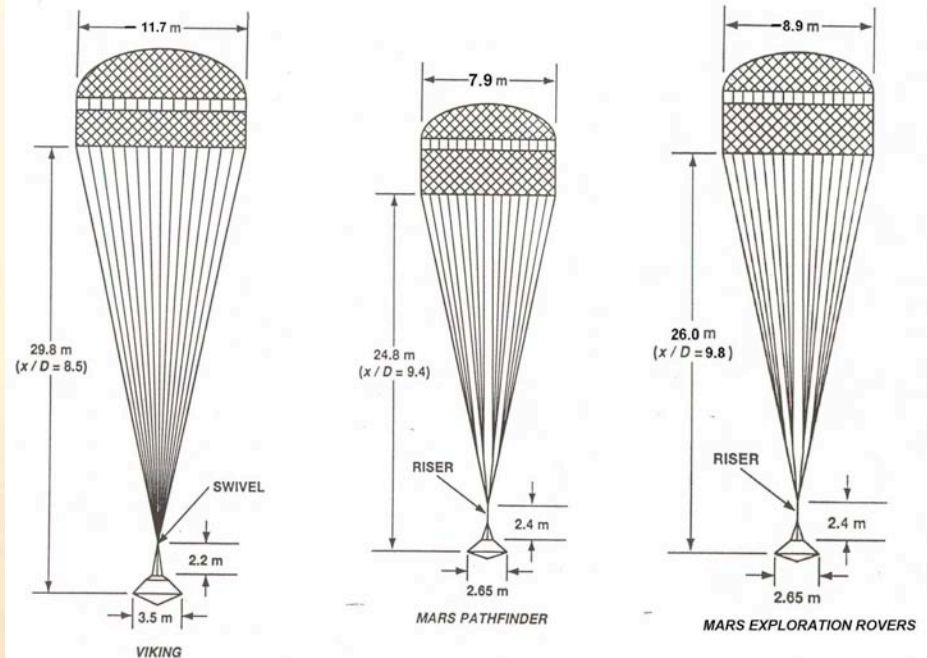
- *The “Supersonic Transition Problem” i.e.*
- *How do we ...*
 - *Slow from Mach 5 to less than Mach 1 ..*
 - *Undress and re-orient*
 - *Kill velocities and attitude rates*
 - *Translate to landing site*
 - *BEFORE hitting the ground? (at >100k ft density altitude)*
- *This is a mystery that no viewgraph can solve.*
 - *Massive clustered supersonic chutes? Inflatables? Super-sonic Prop?*





Paradigm Shift for Robotic Mars EDL in 2010's

- *For the past 30 years, the robotic Mars EDL community has stood on the shoulders of the Viking giant.*
- *All Mars EDL systems flown and envisioned to date have been constrained to live in the Entry system and supersonic decelerator (parachute) capability envelope developed for the Mars Viking test program.*



- *It has recently become clear that the end of this “spiral-like” era may be at hand.*
 - *New supersonic decelerators are needed to land MSR.*
- *It is quite likely that the Mars program will launch into a new phase of development testing to enable this paradigm shift.*
- *This new effort is likely to ripple forward to the next 30 years and may become the new giant for others to stand on including the human Mars precursors and human flights.*



Looking Ahead to Spiral 4

- It makes sense to ask the experienced robotic Mars team to help tackle the challenges and enormous uncertainties in developing the needed capabilities for Spiral 4.
 - The Robotic Mars team and Human exploration EDL communities within NASA and its contractors are the same bunch!
 - About 50 folks spanning a wide range of core EDL competencies that can be found nowhere else on Earth.
 - Pioneer, Vertigo, LMA, ARA, JPL, ARC, JSC, LaRC, GRC. MSFC ...
 - Many were part of the team who built up the BMD capability for the DoD as well as Projects Mercury, Gemini and Apollo.
 - These folks are chomping at the bit to help ... they know what to do.
- We must work jointly (ESMD/SMD) to make the progress needed in a new super-sonic decelerator we both need.

Next Steps

Doug McCuiston
NASA HQ/Mars Program Director



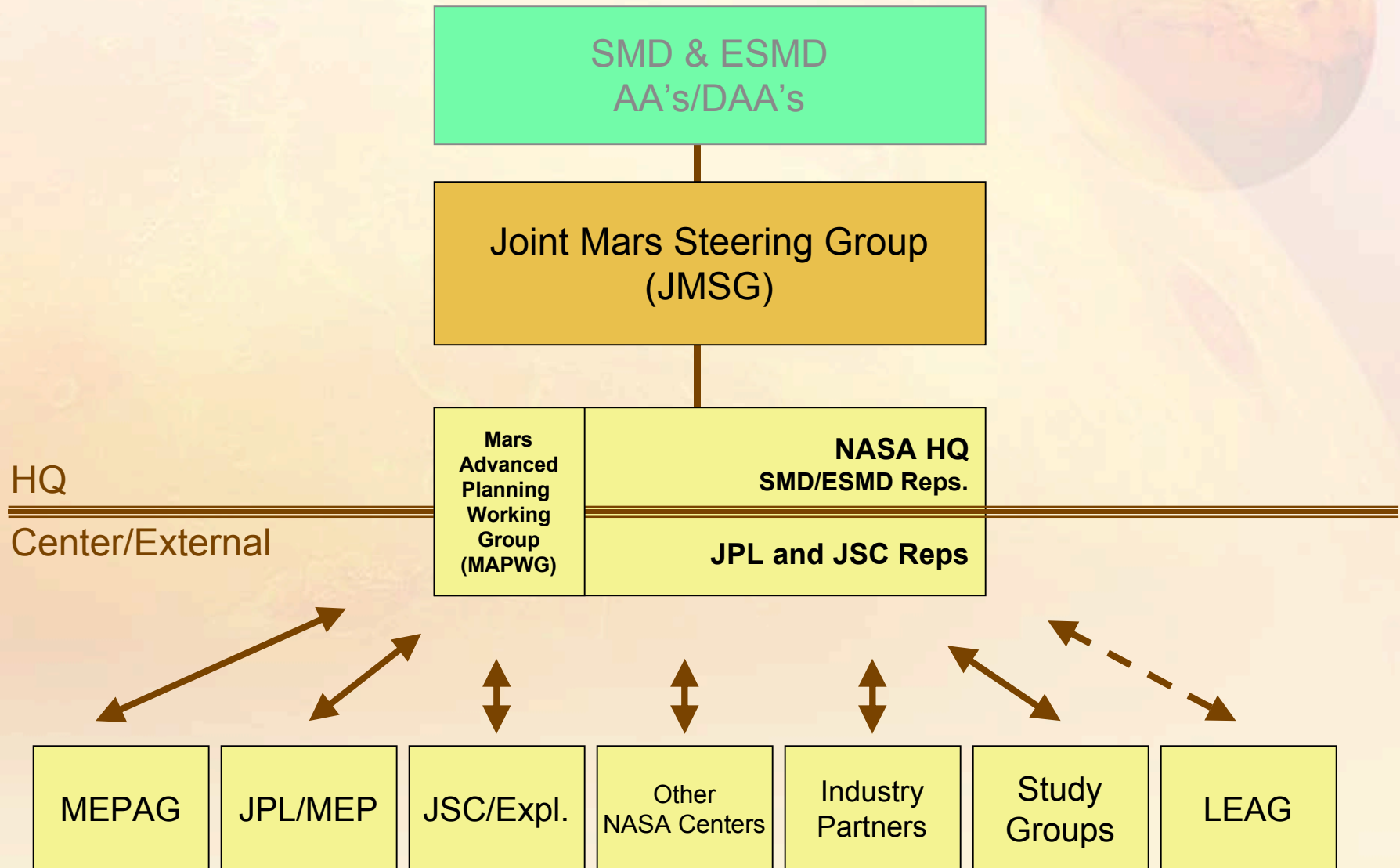


Key Elements in Taking the Next Steps

1. **Organization**: Increase integration and interaction of SMD/MEP and ESMD for Mars Human Exploration planning and execution
2. **Forward Planning**: Jointly commission planning activities, technology and mission development
 - Initially focus on early- and mid-phases
 - Develop strategy for the next decade and beyond



1. Organized SMD/ESMD Mars Collaboration





1. Organized SMD/ESMD Mars Collaboration (con't)

- SMD/ESMD Joint Mars Steering Group (JMSG)
 - HQ, Senior-level membership
 - ESMD/DD Development
 - ESMD/DD Technology
 - ESMD/DD Requirements
 - (ESMD/DAA)
 - SMD/MEP Director
 - SMD/LERP Director
 - (SMD/DAA-Programs)
 - Steerage, decision-making, and review of studies, technologies, measurements, testbeds, etc.
 - Regular coordination/decision meetings (bi-weekly?)
- HQ/Center-level cross-cutting Mars Advanced Planning Working Group (MAPWG)
 - ESMD/SMD Mars Program Exec's & Coordinators (Connolly, Trosper, Lavery, etc.)
 - MEP Program Office & JSC/Human Exploration Office



2. Forward Planning

- Initiate JMSG
 - *Joint* organization capitalizes on MEP's historical focus on Mars, while ESMD is focusing on the Moon
- Initiate MAPWG studies
 - Schedule and decision path for near-term MHP activities
 - Capitalize on this study's recommendations
 - Integrate precursor activities at locations other than Mars
 - Determine next-decade Testbed's objectives and decision path
 - 2011/2013 "mission" definition; milestones for pre-Formulation
 - Identify and initiate technology investments
 - Detail industry involvement—scope and timing



2. Forward Planning (con't)

- Reconcile with Mars Strategic Roadmapping results
- Engage industry through competitive contracts
 - Defined by MAPWG studies
 - Funded jointly by ESMD/SMD
- Identify future large-scale collaborative opportunities
 - Astrobiology Field Laboratory (AFL)
 - Second mid-to-late phase Mars Sample Return (2018-2028)
 - Possible human-scalable demonstration opportunity
 - Multiple objective opportunity
 - EDL—major sub-scale, but scalable
 - Complex surface operations (ISRU?)
 - Sample exploitation of large-quantity sample



Conclusions

- Initial analysis of measurement and technology/infrastructure requirements has yielded excellent framework for moving forward
 - Gap analysis provides focus
- The MEP science program strongly supports MHP needs
 - Additional study can allow greater mutual support
- Need to get started now on definition of Testbeds, and developing technologies
 - EDL is the “long pole”, and needs significant planning and investment now, *by us all*
- Concur on establishment of JMSG and MAPWG
 - MAPWG to develop study plans & milestones for JMSG review in March/April



Back-up



Task Guidelines

- Aim for human mission to Mars in our century's 4th decade, 2030
- First dedicated precursor opportunity -- 2011
- Consider only activities that should be performed at Mars (additional requirements for earth, space-station or Lunar based activities will be included in a later task)
- Science robotic missions will continue; synergy between science mission and robotic precursors will be sought
- Infrastructure associated with science missions, e.g., 2009 Telecom Orbiter, is available
- Perform qualitative analysis of cost, risk, and performance effects based on expert opinion. Inadequate data on human missions to Mars exists for a quantitative analysis.
- Consider requirements with major architectural impacts (i.e. system of system) higher priority than those without.



Summary of High Priority Findings

Early Phase (launch 2011-2016)

- Measurement objectives (dust, atmosphere, biohazards, water, etc.)
- Atmosphere/regolith ISRU demos
- Aerocapture (70° cone) demo



Summary of High Priority Findings—2

Mid Phase (launch 2018-2022)

- Subscale demonstration of a human-scalable landing system
- Pinpoint Landing
- Subscale demonstration of a human-scalable ISRU surface system
- Radiation shielding properties of regolith
- Connector durability and materials degradation

Late Phase (launch 2024-2028)

- Detailed surface reconnaissance of a selected first human landing site
- Full-scale “dress rehearsal” of the human mission key systems:
 - Landing
 - ISRU
 - Ascent
- Infrastructure Emplacement e.g:
 - Telecom orbiters
 - Landed infrastructure systems



Science/Human Precursor Observations

- The Science Program as designed, is a strong contributor to human precursor needs, e.g.
 - The current decade's Portfolio
 - Contribute to search and characterization of accessible water
 - Odyssey Neutron Spectrometer
 - MARSIS Radar (MEX)
 - SHARAD Radar (MRO)
 - Phoenix Ground Truth
 - Neutron Spectrometer (MSL)
 - The next decade's Portfolio
 - Will conduct some key measurements and demonstrations
 - Biohazards MSR may be the only comprehensive approach
 - Dust MSR, AFL
 - Pinpoint Landing MSL, MSR
 - Aerocapture ST-9, MSR



Science/Human Precursor Observations (cont'd.)

- Some Human Precursor needs contribute fundamentally to expanded science knowledge
 - Dust
 - Biohazards
 - Water characterization
- Some Human Precursor items are likely distinct from the science program
 - ISRU and accessible water characterization
 - Human-scalable Landing System
- Program synergy is possible and preferable, but it needs to be done collaboratively and deliberately executed



Human-Scalable Landing Technologies

Heavy Lander Entry, Aero-Maneuver and Deceleration

- Atmosphere Entry, Aero-maneuver, Deceleration and Soft Landing for human exploration of Mars
- Capability to meet human EDL constraints (e.g. Max. G-force limits, pinpoint landing requirements needed for pre-emplaced mission elements) with subscale robotic elements, scalable to human scale in following decade.

Research Issues and Benefits

- Achieve control authority needed for PPL within human G-limits
- To date, most attention paid to Mid-L/D entry vehicle concepts, combined with high mach parachute & range of soft landing approaches—other concepts possible
- Need additional systems studies and Aerocapture experimentation to set clear direction, followed by Earth Testing, culminating in late decade robotic human precursor missions to demonstrate proof of concept



Approximate Development Budget in '05 \$M

Year	'05	'06	'07	'08	'09	'10	'11	'12	'13
Aeromaneuver - Entry Vehicles	-	-	5	5	10	20	30	30	35
Aeromaneuver - Deceleration	-	-	5	5	10	20	20	25	30
PPL System Integration	-	-	-	-	5	10	10	10	10
TOTALs		-	10	10	25	30	60	65	75

Enables:

- Robotic human-scalable landing demo late in the next decade



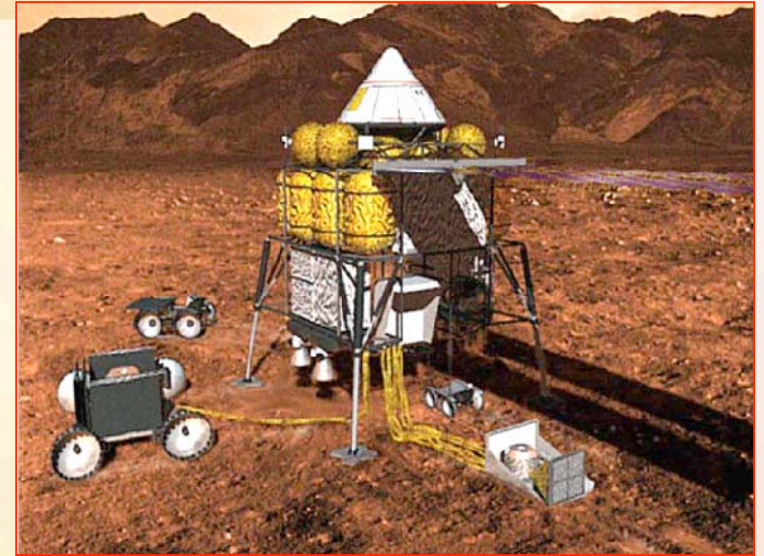
ISRU Technologies

In-Situ Resource Acquisition/Utilization

- Acquire Mars water/ice from subsurface ice and CO₂ from atmosphere, convert to methane and oxygen for MAV propellants

Research Issues and Benefits

- ISRU propellant production enables lower-mass Earth launches
- ISRU consumables production reduces/eliminates need for recycling
- Requires:
 - Detecting and characterizing H₂O form, extent and properties,
 - Robotic mobile mining (rover) to acquire ground material for water extraction, &
 - Chemical conversion, propellant storage and subscale MAV propulsion



Approximate Development Budget in '05 \$M

Year	'06	'07	'08	'09	'10	'11	'12	'13
Ice Exploration & Evacuation	5	5	5	10	20	25	40	40
Chemical Conversion	2	4	4	2	3	3	4	5
MAV Propulsion	-	-	-	-	-	2	4	6
2/27/05 TOTAL	7	9	9	12	23	30	48	51



Enables:

- Low volume/rate ISRU demos early in the next decade
- High volume/rate ISRU demos late in the next decade



Instrument Technology Investments

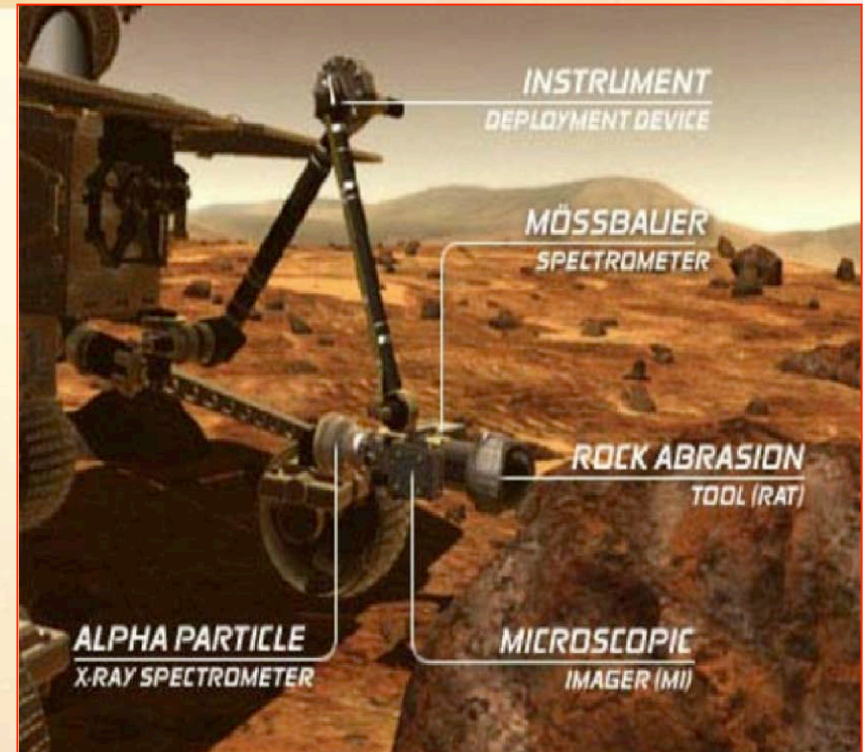
Precursor Instruments

Ensure Safe Future human Operations on Mars

Research Issues and Benefits

Provides capability to carry out SSG-required surface measurements on next decade missions:

- Dust characterization
- Toxic chemicals in soil
- Detect water in all forms
- Physical properties of Mars surface
- Atmospheric properties
- Radiation above and below surface
- Atmospheric measurements



Approximate Development Budget in '05 \$M								
Year	'06	'07	'08	'09	'10	'11	'12	'13
Prototypes	2	3	3	3	3	4	4	4



Enables:

Quality measurements on missions throughout next decade



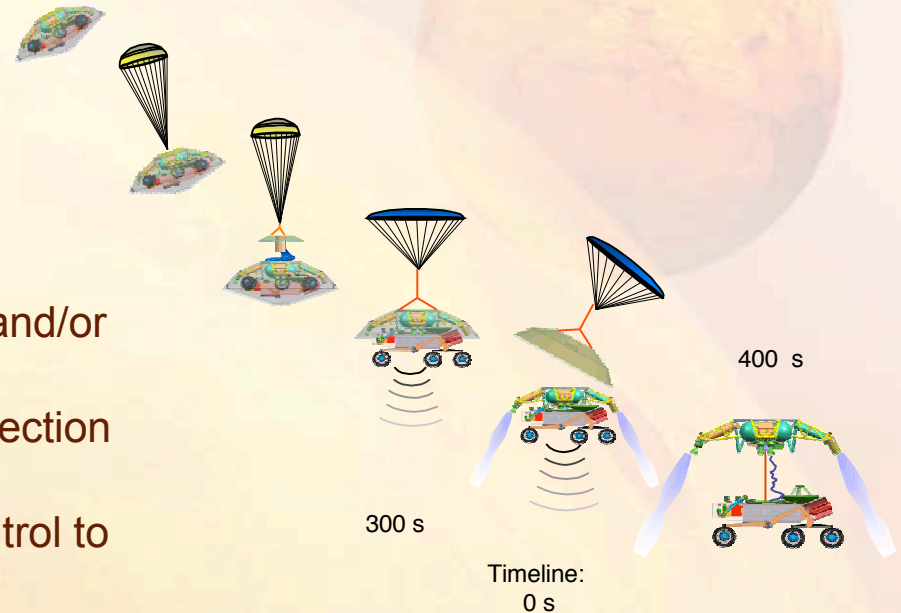
Required Pinpoint Landing Program (Currently Funded in SMD)

Pinpoint Landing System

Provides <100-m landing accuracy

Research Issues and Benefits

- Image-based terrain relative navigation
- Improved approach navigation using OPNAV and/or S/C- to-S/C navigation
- Fuel-optimal descent with large horizontal correction capability
- Steerable parachute provides final landing control to overcome winds
- Delivery to < 100 m
- Earth-based drop/helo tests to TRL 6



Approximate Development Budget in '05 \$M

Year	'05	'06	'07	'08	'09	'10	'11	'12	Total
Develop to TRL 6	4	10	12	4	-	-	-	-	30
Flight Demo	-	-	-	14	16	8	3	1	42
TOTAL	4	10	12	18	16	8	3	1	72



Enables:

Demo on testbed or science mission early in the decade